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OAK FUNGUS IN ORCHARD TREES

BY

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Oak fungus (*Armillaria mellea*) is a root disease of widespread economic importance in California. It attacks most of the common deciduous fruit trees and is also found on many other plants including annuals and perennials. As its common name indicates, the native oak trees are generally considered the source of infection. The disease spreads underground and often kills orchard trees over a considerable area. Trees replanted in infected orchards from which diseased trees have been removed usually die within a few years unless resistant species are used.

APPEARANCE AND BEHAVIOR

The characteristic behavior of trees infected with this disease makes it comparatively easy to identify the fungus. Diseased trees may die at any time during the year. Their roots show flat white fan-shaped mycelium (a thin felted sheet of fungous threads) between the bark and the wood. This mycelium is usually confined to the roots, and only in exceptional cases does it extend into the trunk above ground. The odor of a freshly dug root from a diseased tree is distinctive and is described by W. T. Horne as having a "sharp, rather agreeable mushroom smell." The presence of the flat white mycelium and peculiar mushroom odor serves as an excellent means of identifying this disease. Roots of fruit trees attacked by it decay rather quickly. The advancing edge of the fungus is usually shown by a darkening of the wood.

Slender brown or purple thread-like cords are sometimes found on the surface of the roots. These root-like organs are the rhizomorphs by which the fungus spreads underground from tree to tree. It is believed that the rhizomorphs are the principal means of spreading the disease. They are not always present in abundance on fruit tree roots and are often passed unnoticed. Whenever one of these rhizomorphs

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comes in contact with a tree root, it quickly enters and in time infects the entire root system.

During the rainy season clumps of toadstool sporophores often appear near the crown of the diseased trees. These toadstools are of a light tan color on the top, usually showing light brown scales. The lower surface is white and is made up of fine delicate structures known as gills, which bear the spores or reproductive bodies. The size of these clumps varies considerably. They may consist of comparatively few toadstools, or they may be as much as two feet in diameter. The spores, which are produced in great numbers, apparently do not attack living plants, and hence there is nothing to be gained by destroying the toadstools. Ordinarily, the whole clump turns dark within a few days, becomes infested with the larvae of certain fungous gnats, and melts down to a slimy mass. While the spores are not thought to be important in disseminating the disease, the presence of one of these clumps indicates that the fungus is established in the tree and that the tree is doomed to die within a comparatively short time. Usually, the whole tree dies suddenly (fig. 1) but occasionally one side may die and leave the remainder apparently healthy. This condition seems due to the fact that the roots on one side are killed before the disease has become established throughout the root system. The remainder of the tree generally dies within a year or two. When a fruit tree has once become infected, it is inevitably killed. After the disease reaches the crown, treatments with disinfectants or by surgery have not proved effective. There are but few, if any, authentic cases where an infected tree has survived more than one or two seasons after treatment.

One of the chief characteristics of the disease is its manner of spreading. From the original source of infection, the disease spreads outward from tree to tree in all directions. The infected area is irregularly circular in outline, and the border usually contains one or more trees showing various stages of injury.

SOURCES OF INFECTION

In the treatment of any plant disease, a knowledge of the source of infection is important in order that the disease may be stopped, if possible, before it attacks plants under cultivation. *Armillaria mellea* is found on many native species, including the oak, willow and madrone. The indigenous oak trees probably form the chief source of infection, but it is not known whether all oaks carry the disease.

It is not difficult to find, in orchards which have been long owned by one family, authentic cases where the disease has developed in areas from which oak trees had been removed many years before. Oak roots

decay very slowly and may remain in the soil twenty or thirty years after the tree has been cut down. It seems as if the disease attacks the roots of the fruit trees only when they come into contact with the oak root fragments. Thus, the fruit trees may not be killed for many years after the orchard is planted. Apparently the pieces of oak roots are a potential source of infection until after they are completely decayed. It has also been observed that many *Armillaria* spots develop in orchards planted along streams or old water courses. The source of



Fig. 1.—Mature apricot tree killed by oak fungus during the growing season.

infection in these cases may be the native vegetation along the banks or the fragments of roots carried down by the flood waters and deposited on the adjoining land and covered with sediment.

Nursery trees may also form a source of infection, as the disease has been found, in a few cases, on nursery trees. It is probable that only a very small proportion of trees are diseased as they come from the nursery.

In Tasmania,* *Armillaria* has been reported to have spread from underground drains made of wood. When tile was substituted for the wood, the rate of spread of the disease was appreciably diminished.

* Bulletin 57. Root-Rot of Fruit Trees, by H. M. Nicholls. Agricultural and Stock Department, Tasmania.

Relative Susceptibility of Species.—Nearly all of the deciduous fruit trees grown in California are susceptible to the disease. Only three exceptions have thus far been discovered. The three species whose resistance seems to be well established, are the French pear, *Pyrus communis*; Northern California Black Walnut, *Juglans californica hindsii*; and the Fig, *Ficus carica*. Oak fungus also attacks raspberries, blackberries, and many ornamental shrubs, and has been found on rhubarb and potato plants. English or Persian walnuts (fig. 2) and many hybrids between the English and other species are not resistant. *Prunus davidiana*, recently introduced as a stock for peaches, and pear trees on Japanese stock, which may include a mixture of several species, show more or less susceptibility. Some of the pear root stocks used recently for their resistance to pear blight, have not been grown long enough in districts infected with *Armillaria* to determine their degree of resistance.

Of the three principal rootstocks used for stone fruits, observation seems to indicate that myrobalan is the most resistant, surpassing either the peach or the almond root. Some growers are replanting their infected areas with myrobalan seedlings, to be topworked later with the desired varieties. None of these plantings are as yet old enough to show decisively whether or not this method is better than the usual practice of planting budded nursery trees. In some districts the apricot root on heavy soil seems to show a comparatively high degree of resistance, but on sandy soil, this root is killed very quickly. Peaches and cherries are known to be susceptible.

Factors in the Rate of Spread of the Fungus.—The kind of soil in which the fruit trees are growing usually seems to exert little influence on the rate of spread of the fungus. The disease has been found in soils of many types, ranging from light sand to heavy clay and adobe, but, dry, gravelly soils and the sandy sediment soils often found along creek beds seems to show a somewhat more rapid spread of the disease than do the heavy clay types.

In some parts of the state, there is an impression among growers that irrigation tends to increase the rate of spread of the disease, but this belief has not, as yet, been substantiated. Irrigation may be a means of causing the disease to die out by hastening the decay of infected roots. This, if true, would be a means of quickly making an infected piece of soil safe for planting. The rate of spread of the disease shows great variation in different regions. The loss may range from one or two to forty or fifty trees a year. Where the annual losses are large it appears that several diseased spots have coalesced to form

a single large area, covering sometimes several acres. Limited observations seem to show that with prunes and apricots in adobe soil, the rate of spread is considerably slower than where these fruits are on gravelly or loamy soil.

The vigor of the individual tree does not seem to have any effect on its resistance to the disease. Young and vigorous trees are as liable to attack as old ones. With old trees, the presence of the disease may



Fig. 2.—Walnut tree on English walnut root killed by oak fungus.

be suspected for a year or more before death occurs, but young trees die very quickly after the first indications are given by the drying and falling off of the leaves.

The belief has long been held among growers that so long as its native host is alive, the fungus does not leave it to attack fruit trees. While this contention may be difficult to prove, it is an interesting fact that many examples have been found of prune and apricot trees growing for years in close proximity to oak trees without contracting the

disease. There is some evidence to show that *Armillaria* exists in an oak tree but does not kill it. While the oak tree is living, the fungus is apparently unable to penetrate to the cambium layer. After the death of the host the disease spreads throughout the dead or dying roots. In the case of fruit trees, the fungus is apparently able to penetrate to the cambium immediately.

History of a Typical Orchard Infected with Armillaria.—A striking example of how oak fungus spreads is shown in the accompanying map of an orchard in Santa Clara County (fig. 3). The part of the orchard shown on the map originally contained 1297 prune and apricot trees planted in 1894 on the square system, 22 feet apart. French prunes, part of which were grafted on myrobalan and part on almond root, made up the majority of the planting. The apricots were top-worked to Sugar prunes when seven years old. It is interesting to note that these trees, as shown in the northeast corner of the map, have withstood the advance of the disease fully as well as, if not better than, the French variety on Myrobalan and on almond root.

Losses first occurred when the trees were five or six years old, and have been continuous since that time. Where trees died the vacancies were refilled with prune trees, but these second plantings did not long survive. Next, apples were tried, and although somewhat more resistant to the fungus, they were removed because this fruit did not pay. Then, for a time the vacant spaces were devoted to garden vegetables and alfalfa. Finally, walnuts were planted. Part of the first planting of walnuts was on English root. These trees were killed after a few years. The remaining walnut trees which were grafted on the California black walnut stock survived and at the present time are about 12 or 14 years old and are bearing satisfactory crops.

Judging from the apparent age of the replanted walnut trees the area now infected with oak fungus started from four or five points or sources. These original spots grew in size and finally coalesced to form the irregular shaped area shown within the dotted lines on the map (p. 7). It seems that one area began near the lower southeast corner, where the orchard approaches the banks of a creek. It is probable that infection started from the native trees along the bank. Other infected areas developed in various places and gradually spread until they came together to form one large diseased patch. The owner of the orchard still remembers the approximate location of the oak trees which were cut down more than 30 years ago. In some cases the location of these oaks apparently coincides with what seem to have been the beginning points of the disease in the orchard.

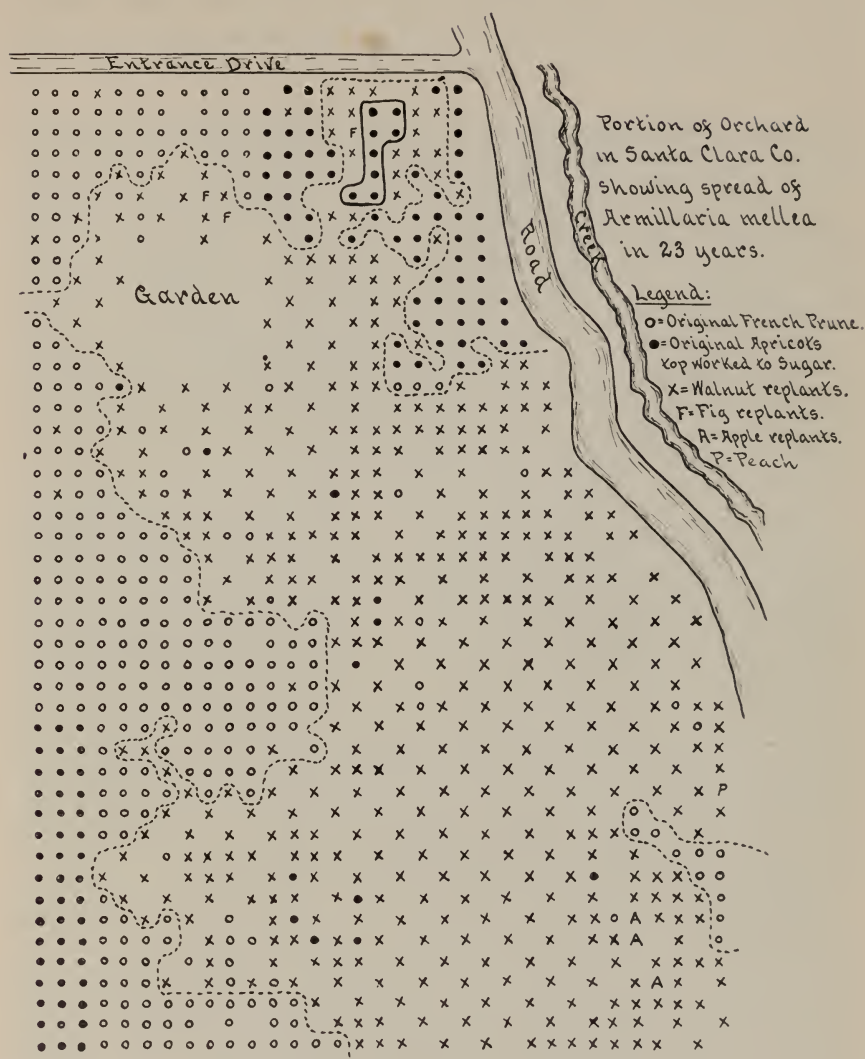


Fig. 3.—A typical example of an *Armillaria*-infected orchard, and how the disease slowly but surely spreads over the whole area if not checked during its early stages. This part of the orchard originally contained 1297 prune and apricot trees planted in 1894. Missing places are now principally planted to walnut trees on resistant stocks.

At the present time approximately 860 trees of the original planting have been killed. This amounts to a loss of nearly 66 per cent in 23 years. In other words, the average loss was about 37 trees a year on an area of about 14 acres. The economic loss resulting from the death of 37 mature prune trees each year, together with the non-productive period which must elapse before the replanted walnuts come into bearing amounts to a considerable sum.

A study of this orchard, which is no different from many others in various parts of the state, is of peculiar interest, because of the very evident lessons it imparts. It shows first, the inexorable progress of the fungus when once established in a prune or apricot orchard; second, the economic loss resulting from the death of bearing trees; and third, the best solution as yet found for this problem: viz., replanting with disease-resistant trees such as walnuts on California black walnut root.

METHODS OF CONTROL

Up to the present time no method of treatment intended to control this disease, after it is discovered, has been effective. The solution of the problem seems to lie in lessening the losses by checking the spread of the fungus. Isolating the diseased trees by digging trenches around the diseased area or by replanting with resistant stocks after the original trees have died will accomplish this. Trenching around the infected area at a safe distance beyond the visible limits of the fungus may be expected to give a reasonable amount of protection for the remainder of the orchard. This method, however, is practicable only when the diseased area is relatively small. It is also beset with danger because diseased roots may be left outside the barrier.

In the case of many plant diseases, one of the principal methods of control is by pruning off diseased parts and by burning or plowing under infected material. This method is not applicable to controlling a root disease of a large tree. When a diseased tree is dug out of the soil, it is not practicable to remove all of the roots. The idea of disinfecting the soil presents itself in this connection.

Various chemicals have been tested for this purpose. Up to the present time, the tests have not been particularly successful. Disinfecting the holes from which diseased trees have been removed with such materials as copper sulfate, formalin, sodium cyanide and carbon bisulfide has not proved to be a reliable method of permanently preventing infection of the replanted trees. Neither has the application of hydrated lime to the soil around trees adjoining diseased areas proved to be effective in preventing the spread of the fungus (fig. 4).

In Tasmania, excellent results are reported from the application of permanganate of potash or iron sulfate on the main roots of trees infected with *Armillaria*. Similar treatments (fig. 4) applied to trees in California using Weed Killer (proprietary arsenic compound).*



Fig. 4.— Partly diseased prune tree with main roots uncovered for treatment with disinfecting materials. No useful results obtained.

permanganate of potash,* iron sulfate,* formaldehyde and Bordeaux, all failed to control the disease. Likewise, treatments with various

* These materials have been used by Col. G. E. Stockle of Mountain View on a commercial scale for several years without success.

chemicals by so-called tree doctors have not checked the spread of the fungus.

Barriers.—*Armillaria* spreads underground from tree to tree by means of root-like fungous strands known as rhizomorphs. Healthy



Fig. 5.—Portion of a narrow concrete barrier built around an oak fungus area to prevent spread of the disease.

trees are thus infected from adjacent diseased ones. Theoretically, the disease can be checked by preventing the underground spread of these rhizomorphs. Various methods to accomplish this purpose have been suggested and carried out to a limited extent. The chief idea

in this method of control is to dig around the diseased area a trench of sufficient depth to extend below the area occupied by roots. This trench may simply be refilled after cutting off all crossing roots and later reopened for the same purpose; or it may be lined with material



Fig. 6.—Because this one small infected root was outside the wall, the barrier, faintly shown on the right of the photograph, failed to prevent the spread of the fungus. The barrier should have been placed one tree row farther away from the diseased area.

like tar-paper; or it may have constructed in it a narrow concrete (fig. 5) wall extending from slightly below plowing depth to the bottom of the trench.

The chief objection to the use of the concrete barrier is its cost. The enclosed area is, therefore, usually made as small as possible. The danger in this practice lies in the fact that although the trees bordering the diseased area are apparently healthy, they may have one



Fig. 7.—Stump of English walnut tree killed by oak fungus. The graft union was covered with soil and the disease entered the scion above the graft union. The black walnut root was not injured and sent up several sprouts after the top had died.

or more infected roots. In this case, the disease soon makes its appearance outside of the barrier. This has actually happened in two instances known to the writer. In one case when a tree outside of the

barrier died, the source of infection was traced to a root which extended to the wall, but which was not observed to be infected when the barrier was built (fig. 6). For safety the barrier should be put not closer than between the second and third rows of healthy trees surrounding the diseased area.

CONCLUSIONS

Oak fungus is a root disease attacking many common deciduous fruit trees and ornamentals. All root stocks used at the present time for stone fruits are more or less susceptible to attack. Apples are usually considered highly resistant, especially if grown on Delicious stock, and the French pear root is practically immune. The fig and California black walnut are also highly resistant to this fungus. If the infected area is limited in extent, as in the case of young orchards when the disease is first noticed, it may be possible to check further progress of the fungus by enclosing the diseased spot with a concrete barrier as described in this paper. When the diseased area is extensive it should be replanted with one or more of the resistant species. In replanting with either pears on French root or with walnuts on black walnut root, care must be taken to see that the graft union (fig. 7) is not covered with soil, because cases have been observed where the susceptible scion was attacked by the disease, while the root was not affected.

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